Interference Case		AMSC	Const'n	Ellipsat	Glob'lst'r	Odyssey	Celsat
Case 1: Backlobe	Io/C1o (dB)	see Note 1	27.9	see Note 1	16.5	20.4	10.4
	Displaced Channels	see Note 1	623	see Note 1	45	109	11
Case 2: Sidelobe	Io/C1o (dB)	see Note 1	-1.4	see Note 1	-5.5	14.9	7.9
	Displaced Channels	see Note 1	1	see Note 1	0	31	6
Case 3: Trans-Hor'n	Io/C1o (dB)	see Note 1	23.4	see Note 1	18.9	38.7	32.3
	Displaced Channels	see Note 1	220	see Note 1	78	7,348	1,710

Table III - I_o/C_{1o} in dB and Number of Displaced Channels per Spread Bandwidth

Note 1: These analyses have not yet been completed.

Table IV gives a summary of the aggregate interference impact on each of the victim systems, taking into account the number of victim beams and spread bandwidths that are simultaneously affected by the interference.

Victim satellite	Aggregate Interference Impact from a single IRIDIUM satellite	
AMSC	Backlobe:	
	Sidelobe:	
	Trans-Horizon:	
Constellation	Backlobe:	312 channels lost; 0.5 voice activity; 8.4 spread bandwidths (total 5,241 voice ccts lost).
	Sidelobe:	None.
	Trans-Horizon:	220 channels lost; 0.5 voice activity; 8.4 spread bandwidths (total 3,696 voice ccts lost)
Ellipsat	Backlobe:	
	Sidelobe:	
	Trans-Horizon:	
Globalstar	Backlobe:	23 channels lost; 0.5 voice activity; 8.4 spread bandwidths (total 386 voice ccts lost).
	Sidelobe:	None.
	Trans-Horizon:	178 channels lost; 0.5 voice activity; 8.4 spread bandwidths (total 2,990 voice ccts lost).
Odyssey	Backlobe:	55 channels lost; 0.4 voice activity; 1 spread bandwidth (total 137 voice ccts lost).
	Sidelobe:	15 channels lost; 0.4 voice activity; 1 spread bandwidth (total 37 voice ccts lost)
	Trans-Horizon:	7,348 channels lost; NO BEAM CAPACITY REMAINING.
Celsat	Backlobe:	5 channels lost; 0.36 voice activity; 8.4 spread bandwidths (total 120 voice ccts lost)
	Sidelobe:	3 channels lost; 0.36 voice activity; 8.4 spread bandwidths (total 72 voice ccts lost)
	Trans-Horizon:	1,710 ch lost; 0.36 voice activity; 8.4 spread bandwidths (total 41,040 voice ccts lost)

Table IV - Aggregate Interference Impact on Each System

4.4.5 Frequency and Duration of Interference Occurrence

The frequency and duration of interference occurrences will depend on the relative geometries of the Iridium and victim satellite constellations, and on the antenna characteristics of the satellites. Table IV summarizes the general observations made in this respect for all the systems, with the exception of Globalstar, where a detailed computer simulation has been performed, and the results provided in Annex 4.2.

Victim satellite	Frequency and Duration of Interference Occurrence	
AMSC	Backlobe:	Always present in one beam or another between (max) value and (max - 1dB)
	Sidelobe:	Potentially present in all beams continuously
	Trans-Horizon:	Always present in certain beams
Constellation	Backlobe:	Similar to Annex 4.2
	Sidelobe:	Similar to Annex 4.2
	Trans-Horizon:	Always present in certain beams
Ellipsat	Backlobe:	Always present in one beam or another between (max) value and (max - 6dB)
	Sidelobe:	Potentially present in all beams continuously
	Trans-Horizon:	Always present in certain beams
Globalstar	Backlobe:	Refer to Annex 4.2
	Sidelobe:	Refer to Annex 4.2
	Trans-Horizon:	Always present in certain beams
Odyssey	Backlobe:	Always present in one beam or another between (max) value and (max - 2dB)
	Sidelobe:	Potentially present in all beams continuously
	Trans-Horizon:	Always present in certain beams
Celest	Backlobe:	Always present in one beam or another between (max) value and (max - 1dB)
	Sidelobe:	Potentially present in all beams continuously
	Trans-Horizon:	Always present in certain beams

Table V - Frequency and Duration of Interference Occurrence

Annex 4.1 Derivation of Iridium EIRP in Various Directions

This annex provides the derivation of the average Iridium backlobe, sidelobe and trans-horizon EIRP spectral densities.

Table A-I below summarizes the Iridium data provided by Motorola on March 11, 1993. It derives the EIRP (per 31.5 kHz channel) as a function of the cell type and for shadowed and non-shadowed users. The average EIRP (per 31.5 kHz channel) is then calculated for the case where 20% of the users experience full shadowing and 80% of the users are not shadowed. The final row of the table is the resulting average weighted EIRP, over all the cell types.

	Iridium Cell Types			
	#16	#12	#6	#1
Number of Cells of this Type per Satellite	3	9	15	21
EIRP required (non-shadowed user)	4.5 dBW	7.0 dBW	9.5 dBW	12.7 dBW
Average fade margin required (20% shadowed users)	6.6 dB	6.6 dB	6.6 dB	9.1 dB
Average EIRP required (20% shadowed users)	11.1 dBW	13.6 dBW	16.1 dBW	21.8 dBW
Ratio of peak to eoc gain	1.5 dB			
Average over beam EIRP required (20% shadowed users)	12.6 dBW	15.1 dBW	17.6 dBW	23.3 dBW
Average EIRP (averaged across all cells) (including 6-fold re-use)	28.5 dBW per 41.67 kHz			
Average EIRP (averaged over horizon-pointing cells)	23.3 dBW per 41.67 kHz			

Table A-I - Derivation of Iridium EIRP

Motorola has also indicated that it is appropriate to assume a voice activity factor of 0.375, which reduces the EIRP values in Table I by 4.2 dB.

Motorola has also indicated that the satellite backlobe antenna gain will be better than -39 dB relative to mainlobe beam peak, and the sidelobe antenna gain will be better than -20 dB relative to mainlobe beam peak.

This results in average EIRP levels, per 41.67 kHz (occupied bandwidth) as follows:

Backlobe EIRP:	-14.7 dBW per 41.67 kHz
Sidelobe EIRP:	+4.3 dBW per 41.67 kHz
Mainlobe (Trans-Horizon) EIRP:	+12.4 dBW per 41.67 kHz

When expressed per Hz, these values become:

Backlobe EIRP:	-60.9 dBW/Hz
Sidelobe EIRP:	-41.9 dBW/Hz
Mainlobe (Trans-Horizon) EIRP:	-33.8 dBW/Hz

Annex 4.2 Coupling of Globalstar and Iridium Satellites

Motorola has claimed that the coupling from its system into the Globalstar system is infrequent and of short duration. This is not the case. Computer simulations of the two orbit constellations show that the coupling is continuous over the world even for small ranges.

The simulation kept statistics on the occurrences of an Iridium satellite within three different coupling distances from a Globalstar satellite. The distances are 944 km 1675 km and 1926 km. The analysis was performed with a computer simulation which operated with the Globalstar satellite system and the Iridium satellite system simultaneously. Statistical data was compiled to examine the percentage of time the Globalstar system was within a certain coupling distance to an Iridium satellite.

The cases that were analyzed were on a world wide scale. The method simulated the orbital constellations for many orbital days to determine statistically the percentage of time that an Iridium satellite is coupled with a Globalstar satellite. Data was also accumulated to determine the average and maximum duration time that the condition occurs. It was found that for Globalstar these couplings occurred for a significant portion of an orbit. The simulation was run for a long period of time to collect maximum and average duration and the percentage of time that the condition occurs. Observation of the simulation shows that when the Iridium seam is near a Globalstar satellite the coupling of a Globalstar satellite and two Motorola satellites occurs at distances less than 800 km. This worst case and other cases involving multiple Iridium satellites have not been addressed. Table 1 gives the simulation results.

TABLE 1
Number of Globalstar Satellites, maximum duration, average duration that Globalstar satellite is within given distance to an Iridium satellite

Distance (km) (min.)	# of GS satellites	maximum (min.)	average
944	6	6	1.6
1675	26	21	3.8
1926	37	39	6.7

Table 1 shows the minimum number of Globalstar satellites that have at least one Iridium satellite within a given distance along with the maximum and average duration. For example, at any given time there are at least six Globalstar satellites that have at least one Iridium satellite within 944 km. This maximum duration time that an

Iridium satellite couples with a Globalstar satellite within 944 km is 6 minutes and the average duration time is 1.6 minutes.

The same simulation was done on an area limited to North America excluding Alaska. This is to illustrate the possibility of interference to Globalstar while serving Canada, Central America and/or South America while Iridium is serving the United States. Table 2 gives the simulation results.

TABLE 2
Number of Globalstar Satellites, maximum duration, average duration that Globalstar satellite is within given distance to an Iridium satellite: North America Only

Distance (km) (min.)	# of GS satellites	maximum (min.)	average
944	1 (57% of time)	6	1.4
1675	2	1 1	2.6
1926	3	25	3.7

Annex 4.3 Calculation of Reflected Signal Power from Iridium Satellite Downlinks into Ellipsat

On page 473 in Skolnik, Introduction to Radar Systems, Skolnik gives the following equation for radar clutter power (i.e. earth reflected power) for the case of near vertical incidence:

$$C = (\pi \, . \, P_t \, . \, A_e \, . \, \sigma^o) \, / \, (64 \, . \, R^2 \, . \, \sin \phi)$$

where ϕ is the grazing angle on the earth from the source.

Note that clutter power is proportional to $1/R^2$ rather than the usual $1/R^4$ found in radar equations. Adapting this equation to yield power flux density at the victim receiver yields:

$$C_{PFD} = (\pi \, . \, P_t \, . \, \sigma^o) \, / \, (64 \, . \, R^2 \, . \, W \, . \, L_c \, . \, \sin \phi)$$

In the average loading case, two Iridium channels will fall into the Ellipso channel bandwidth of 1.1 MHz. Assume that one Iridium channel falls within the Ellipso bandwidth and that the Iridium channel is operating to a shadowed user. Therefore P_t = 2.2 watts (5.5 - 2.1 = 3.4 dBW) as per page 17 of the Iridium Minor Amendment. The distance R corresponds to that from the earth to the Ellipso satellite, since the earth intercepts virtually all of the energy of an inner Iridium beam, but the Ellipso satellite intercepts only a fraction of the energy reflected from the earth, so that R^2 spreading loss applies to the ground-Ellipso path. Assume R = 4,000 kilometers, an intermediate Ellipso altitude. Assume ϕ = 90° or vertical incidence on the earth. L_c refers to additional loss due to the curvature of the earth for high altitude emitters and targets, as in the satellite case. For this study (Iridium's altitude and beamwidths), L_c is around 3.5 dB.

Data from Skolnik's Radar Handbook, Second Edition (figures 13.4 and 13.9 and text on page 13.16ff) indicate that at around 80° incidence angle the cross section density of the sea is around 7 dB square meters per square meter and is constant with sea state. At 90° incidence, the cross section density varies from as much as 15 dB for calm seas to around 10 dB with higher seas. These figures are stated to be only weakly dependent on frequency. For purposes of this analysis, since angles of incidence approaching normal (90°) are assumed, a cross section area density of 10 dB is assumed.

Substituting and solving:

$$C_{PFD} = -195.6 \text{ dBW/Hz}$$

One shadowed user in each neighboring beam per MHz would add around another 2.4 dB total, yielding:

C_{PFD} = -193.2 dBW/Hz

Compare to PFD at an Ellipso satellite at the same altitude (with $EIRP_{ellipso}$ = -2 dBW since the satellite is lower in its orbit and the terminal is power controlled correspondingly downward) of:

$PFD_{ellipso}$ = -205.4 dBW/Hz.

Thus, per Skolnik, a single shadowed Iridium channel per beam per MHz per Iridium downlink time slot produces interference roughly equivalent to 16 Ellipso users. Additional simultaneously shadowed Iridium users per megahertz will produce a correspondingly higher amount of interference.

Motorola states in their application that as many as 960 users can be supported in one beam. In this unlikely worst case scenario, around 24 frequency channels would be in use in one beam per MHz instantaneously. Assume these users occur in the beam responsible for the bulk of the reflection energy to the Ellipso satellite. If 30% of them were faded, this would create an interference level of around 115 Ellipso users into an Ellipso satellite. In this case no interference from adjacent beams is assumed, since the satellite would be carrying all its traffic in one beam.

In conclusion, this approach to evaluating the level of interference from an Iridium satellite into an Ellipso satellite concludes that Iridium can not uncommonly generate interference of around the magnitude of 8 to 32 (16 ± 3 dB) Ellipso users into the appropriately pointed beam of an Ellipso satellite. Interference of one to several equivalent Ellipso users could also arise in the sidelobes of adjacent Ellipso beams. There is every reason to believe that this interference mechanism will be relevant also in relation to the other proposed victm MSS systems which will experience interference from the secondary downlink of the Iridium system.

4.5. Suggested Mitigating Effects.

Motorola asserts that certain effects can be employed to avoid "harmful interference" from secondary downlinks into primary uplinks that may occur. Motorola has asserted that since the potentially harmful interference events are predictable in time and space, it will be possible to plan the implementation of these mitigating procedures in advance to avoid harmful interference during the potential interfering event.

The parties subscribing to this report assert that the proposed effects either would not avoid harmful interference from Iridium's secondary downlinks and so are not applicable, or are so complex in implementation as to be infeasible.

Motorola has proposed five basic methods of mitigating potential interference:

4.5.1. Band Segmentation. Motorola's primary method of avoiding mutual harmful interference between the Iridium system and other MSS systems is to operate the systems in different frequency band segments. However, it has been pointed out that even though the Iridium system and other MSS systems may not operate on a co-frequency, co-coverage basis, because of asymmetrical operating authorizations in different regions, in-band interference events could occur unless their effects were mitigated.

4.5.2. Downlink Masking by the Primary Uplink. The Iridium system transmits and receives on the same frequency. When one or more MSS systems are operating co-frequency with the Iridium system and their beam coverage overlaps on the Earth, both systems typically will receive uplink signals from the subscriber units in all co-coverage areas.

On occasion, the other system may also receive the Iridium downlink signals from the backlobe and sidelobe of the Iridium satellite. According to Motorola, this downlink signal will be of lesser magnitude than the uplink signal and therefore will be partially masked by the uplink signal.

The parties subscribing to this Report believe that it is inappropriate to take into account interference from Iridium uplinks when calculating the effects of secondary downlink interference from an Iridium satellite.

4.5.3. Beam Management. According to Motorola, beam management is applicable to the trans-horizon scenario. Under this scenario, beam management would be used to avoid transmission when any Iridium satellite antenna beam transmits into another MSS system's satellite when to do so could cause harmful interference. The satellites of the victim system could be either in a geosynchronous or non-geosynchronous orbit. Motorola has asserted that the potential for harmful interference will be substantially mitigated by managing the Iridium satellite antenna beams so they will not transmit into the other system's satellites.

4.5.4. Frequency Management. According to Motorola, frequency management is applicable to both the trans-horizon and the backlobe/sidelobe scenarios. This technique involves managing the frequencies used by the Iridium system so that no harmful interference would be caused to other MSS systems that would otherwise operate co-frequency in a portion of the frequency band.

If the Iridium system were licensed to operate in a broader bandwidth in one part of the world than another, and the geometry of the satellites in their respective orbits is such that there is a potential for either trans-horizon or backlobe/sidelobe interference, the Iridium satellite would manage its frequencies so that there would be no co-frequency operation during the period of interference susceptibility. Due to the relative velocities of the satellites, the period of interference susceptibility is very short.

Motorola described two frequency management techniques. One frequency management technique includes reducing the total bandwith required by reducing the vocoder data rates and reassigning the operating frequencies to the non-interfering frequency band. After the period of interference susceptibility has passed, the vocoder data rates would again be increased. A second frequency management technique uses the 6-beam reuse pattern of the Iridium system. The frequencies may be managed so that they are not used in a beam where there is a potential for interference.

4.5.5. Antenna Characteristics. According to Motorola, if necessary, the antenna parameters of the interfering satellite system can be modified to accommodate inter- as well as intra-system sharing once the characteristics of other MSS systems are fully designed. This would be accomplished during the initial coordination process between U.S. licensees. Such parameter modifications could include: (1) improved backlobe and/or sidelobe rejection; and (2) cross-polarization between satellites.

4.6. Response to Motorola's Suggested Mitigating Effects.

The parties subscribing to this report assert that Motorola's suggested mitigating effects would not be sufficient to eliminate harmful interference from Iridium secondary downlinks. For example, due to the complexity of Motorola's frequency beam assignment, it is almost impossible to turn off beams or to turn off carriers to avoid interference without having substantial reduction of Motorola's capacity. Moreover, the proposed mitigating techniques are too complex to implement before systems are launched, but should be available for consideration during any international or domestic coordination process. In any event, no burden should be imposed upon users of primary uplinks in order to avoid harmful interference from secondary downlinks.

136

SECTION 5

REALIZABLE CAPACITY/PERFORMANCE ANALYSIS OF PROPOSED SYSTEMS OPERATING UNDER THE TECHNICAL SHARING CRITERIA

5.1 CDMA vs. CDMA

5.1.1 Introduction

This section includes an analysis of the individual and collective calculated capacities (hereinafter referred to as "capacities") of the CDMA applicants' proposed systems, when operating in accordance with a full-band interference sharing arrangement. The system designs depicted in this section are based on those presented in the applications, other FCC filings, and system modifications considered to facilitate sharing. It should be noted that these descriptions do not include all potential methods of optimization which may further enhance operation and permit higher capacities than those represented.

Annex 5.1 discusses the technical rationale behind the use of downlink PFD spectral density and uplink aggregate EIRP areal-spectral density as the primary coordination interface parameters between CDMA MSS systems.

5.1.2 Methodology for the Calculation of Realizable Capacity in the Downlink

The technique used to assess the capacities of the systems is based on a modelling of the systems which takes account of the major factors that will determine the realizable capacities of the systems under actual operating conditions. This approach has been chosen, in preference to a complex computer simulation of the interaction between the systems, in order to gain insight into the factors that are important in determining capacity. An additional reason for this approach is that it is compatible with both the time available and the degree of detail that the FCC's Negotiated Rulemaking Committee is able to entertain.

5.1.2.1 Downlink System Data Required for the Analysis

The following downlink system parameters are required to perform the analysis. Each parameter is briefly defined and described.

(A_d) Baseband Bit-Rate

This is the total downlink baseband bit-rate required for a single voice channel. It should include all signalling overhead.

(B_d) Channel Activity Factor

This parameter (which should be between zero and one) should be included if the system intends to exploit voice activity by reducing the transmit power in the downlink during the natural pauses in speech. This parameter is the numerical ratio of the average power to the peak power accounting for only the power reductions attributed to pauses in speech. Alternatively, if some form of Digital Speech Interpolation (DSI) is implemented, which produces a corresponding channel efficiency gain, this should be included here as the inverse of the average number of virtual channels multiplexed in an individual signal.

(C_d) Total RF Bandwidth

This is the total occupied downlink RF bandwidth used by the system.

(D_d) Minimum Operating Eb/No

This downlink parameter, which is a function of the modulation scheme and modem implementation, is normally represented in dB form, but needs to be converted to a linear power ratio to substitute in the capacity equation.

(E_d) Number of Satellite Beams to Provide CONUS Coverage

This is the total number of downlink beams, irrespective of the number of satellites, used to implement CONUS coverage. If there are separate satellites in the same system providing co-coverage, the beams in the areas of overlap should only be counted once.

(F_d) Beam Frequency Re-Use Factor

This parameter is a measure of the degree to which the downlink frequency band is re-used spatially among the beams. The value of this parameter is "N", where frequencies are re-used once in every "N" beams. For example, a system with re-use in every beam has a value of N=1. A system with full frequency re-use in every third beam has a value of N=3.

(G_d) Average Propagation Margin

This is the downlink power margin required, in dB, at any instant in time, averaged over all the users in the CONUS coverage of the system, used to overcome propagation impairments relative to free space.

(H_d) Average Orbit and Beam Effects

This parameter takes account of the combined effect of downlink range differences and downlink antenna gain contour effects. It is essentially a dB value that is equivalent to the average extra satellite power required to communicate with all the users distributed throughout the area covered by an individual downlink beam, compared to the situation if all those users were located at the optimum location in the area covered by an individual downlink beam, where G/R^2 is at a maximum (G = satellite antenna gain; R = range to the satellite). It accounts for the difficulty of building a perfect satellite antenna.

(J_d) Average Power Control Implementation Margin

This is a dB value which is a result of imperfect downlink power control. It is equal to the average amount by which the link power exceeds the minimum necessary to sustain the link, if power control were perfect.

(K_d) Average Beam Overlap Factor

This takes account of the spillover between downlink beams. It is the ratio, in dB, averaged over all the users throughout the CONUS coverage, of the power from the intended plus adjacent beams to the power from the intended beam only. Its value is highly dependent on the Beam Frequency Re-Use Factor (see item (F_d) above).

(L) Effective Aperture of the Mobile Receive Antenna (A_e)

The minimum effective aperture of the mobile receive antenna under operational conditions, calculated from the corresponding gain at the frequency of 2,500 MHz.

(M) System Noise Temperature of the Mobile Receiver (T_m)

The maximum system noise temperature of the mobile receiver under operational conditions.

5.1.2.2 Downlink Analysis Method

The downlink analysis method can be split into several parts. The first two stages are used to derive the maximum realizable downlink capacity limits for each system, as follows:

(a) Calculate maximum ideal downlink capacity (C_{MID}), using the following formula:

$$C_{MID} = (C_d \,.\, E_d) \,/\, (A_d \,.\, B_d \,.\, D_d \,.\, F_d) \qquad (1)$$

where the letters in the formula correspond to the parameters defined in section 5.1.2.1 above.

(b) Calculate reduction from maximum ideal downlink capacity (C_{MID}), by taking account of the parameters defined in items G_d, H_d, J_d and K_d in section 5.1.2.1 above. These parameters, when each expressed in dB, can be summed to produce the total downlink capacity margin (Δ_D). The maximum realizable downlink capacity (C_{MRD}) can then be derived as follows:

$$C_{MRD} = C_{MID} \;/\; (10\text{^}(\Delta_D/10)) \quad \text{.........} (2)$$

$$\text{where } \Delta_D = G_d + H_d + J_d + K_d \quad \text{(in dB)}$$

The next stage in the analysis is to derive the downlink capacity graph for each system, which relates the realizable capacity of the system to the maximum operating downlink Power Flux Density (PFD), spectral density, ρ_{sd}, for varying amounts of interfering co-polar PFD, ρ_{id}, due to other sharing systems. Refer to Annex 5.1 for an explanation of the significance of these parameters. This is calculated as follows:

First it is necessary to calculate the effective downlink thermal noise equivalent flux density in a 4 kHz bandwidth, ρ_{nd}, for each system, which is given by the following equation:

$$\rho_{nd} = (k \,.\, T_m \,.\, 4000) \;/\; A_e \quad \text{.........} (3)$$

where:

	k	=	Boltzmann's constant (= -228.6 dB)
	T_m	=	Mobile receive system noise temperature (typically = 290K or 24.6 dBK)
	A_e	=	Effective aperture of mobile receive antenna (= -29 dBm² for an omnidirectional antenna at 2,500 MHz)

For the case of an omnidirectional antenna, this equation gives a value for ρ_{nd} of -139.0 dBW/m²/4kHz. This is the equivalent PFD at the mobile receive antenna that would be required to produce the mobile receive system noise temperature corresponding to T_m.

The realizable downlink capacity, C_{RD}, of the system, when operating without other interfering systems present, can now be related to the maximum realizable downlink capacity, C_{MRD}, the maximum operating PFD, ρ_{sd}, and the effective thermal noise equivalent flux density in a 4 kHz bandwidth, ρ_{nd}, by the following equation:

$$C_{RD} = (C_{MRD} \,.\, \rho_{sd}) \;/\; (\rho_{sd} + \rho_{nd}) \quad \text{.........} (4)$$

The impact of interfering co-polar power flux density from other co-frequency systems, ρ_{id}, can also be taken into account using the following equation:

$$C_{RD} = (C_{MRD} \cdot \rho_{sd}) / (\rho_{sd} + \rho_{nd} + \rho_{id}) \quad \text{.......................................(5)}$$

5.1.2.3 Alternative Downlink Analysis Method

An alternative method of calculating the way in which the individual system capacities are dependent on operating PFD was also developed. This method is described in Annex 5.2 and was used by some of the applicants to confirm the results obtained using the method described in section 5.1.2.2.

5.1.3 Downlink Analysis

This section presents the results obtained when the downlink methodology described in section 5.1.2 above is applied to the CDMA applicants' (and Celsat's) proposed MSS systems. The individual system capacity analysis is performed assuming that the full 16.5 MHz RF bandwidth is available to the CDMA systems. The collective combined system capacity analysis is performed for an available bandwidth of 16.5 MHz.

5.1.3.1 Individual System Capacities

Using the equations given in section 5.1.2.2 above, the maximum ideal downlink capacity, C_{MID}, and the maximum realizable downlink capacity, C_{MRD}, for the CDMA applicants' (and Celsat's) systems have been calculated, using current input data provided by the proponents of the systems. This analysis does not take account of the use of orthogonal CDMA, and assumes that all received PFD acts as interference. The input data and results are given in Table 1 below.

System Parameter	Units	AMSC	Constell'n	Ellipsat	Globalstar	Odyssey	Celsat
Baseband Bit-Rate	(kBPS)	3.0	4.8	4.8	4.8	4.8	5.0
Channel Activity Factor	(#)	0.40	0.50	0.40	0.50	0.40	0.35
Total RF Bandwidth	(MHz)	16.5	16.5	16.5	16.25	16.5	16.5
Minimum Operating Eb/No	(dB)	4.0	3.0	3.0	3.5	3.5	4.0
Number of Beams in CONUS	(#)	6	10	10	20	16	149
Beam Frequency Re-Use Factor	(#)	1	1	1	1	1	1
Average Propagation Margin	(dB)	2.00	2.20	2.60	2.00	2.03	2.00
Average Orbit & Beam Effects	(dB)	2.50	3.50	2.60	2.11	2.00	1.70
Average Power Control Impl. Mar.	(dB)	1.50	2.00	1.00	1.00	1.00	2.00
Average Beam Overlap Factor	(dB)	1.09	1.00	1.00	1.04	1.25	3.80
Effective Aperture of Mobile Ant.	(dBm2)	-21.0	-29.0	-29.0	-29.0	-29.0	-29.0
Noise Temp. Mobile System	(K)	325	290	290	290	290	290
Maximum Ideal Downlink CONUS Capacity Limit (see Note 1)	(# of ccts)	32,844	34,467	43,871	[illegible]	61,419	[illegible]
Maximum Realizable Downlink CONUS Capacity Limit (see Note 1)	(# of ccts)	6,419	4,848	8,398	14,678	14,484	62,753

Table 1 (downlink)

Note 1: It is not intended to operate the systems at these maximum realizable downlink capacity limits. Satellite power level constraints will dictate the individual system power levels and corresponding capacities.

Note 2: Motorola believes that certain values for some of the parameters in Table 1 need to be adjusted to reflect what it considers should be used to operate in real world conditions, and therefore cannot agree with the capacity numbers calculated in the table. See Note below.

Using equation (5) from section 5.1.2.2 above, the realizable downlink capacity of the systems, when operating both in isolation and in the presence of other interfering systems, has been calculated, and the results are given in Figures 1 to 6 below. Four curves are given for each system, as follows:

(a) "No interferer": Assumes that the wanted system only experiences self-interference (i.e., no orthogonal CDMA advantage assumed).

(b) "Interferer = Noise - 3 dB": The wanted system experiences both self-interference and an interfering PFD from other systems which is of a magnitude that is 3 dB below the thermal noise level (ρ_{nd} - 3dB).

(c) "Interferer = Noise": The wanted system experiences both self-interference and an interfering PFD from other systems which is of a magnitude that is equal to the thermal noise level (ρ_{nd}).

(d) "Interferer = Noise + 3 dB": The wanted system experiences both self-interference and an interfering PFD from other systems which is of a magnitude that is 3 dB above the thermal noise level (ρ_{nd} + 3dB).

NOTE: Motorola's analysis is reflected in the work of Dr. Peter Monsen dated March 24, 1993. It is assumed that Motorola will include this document in its minority report.

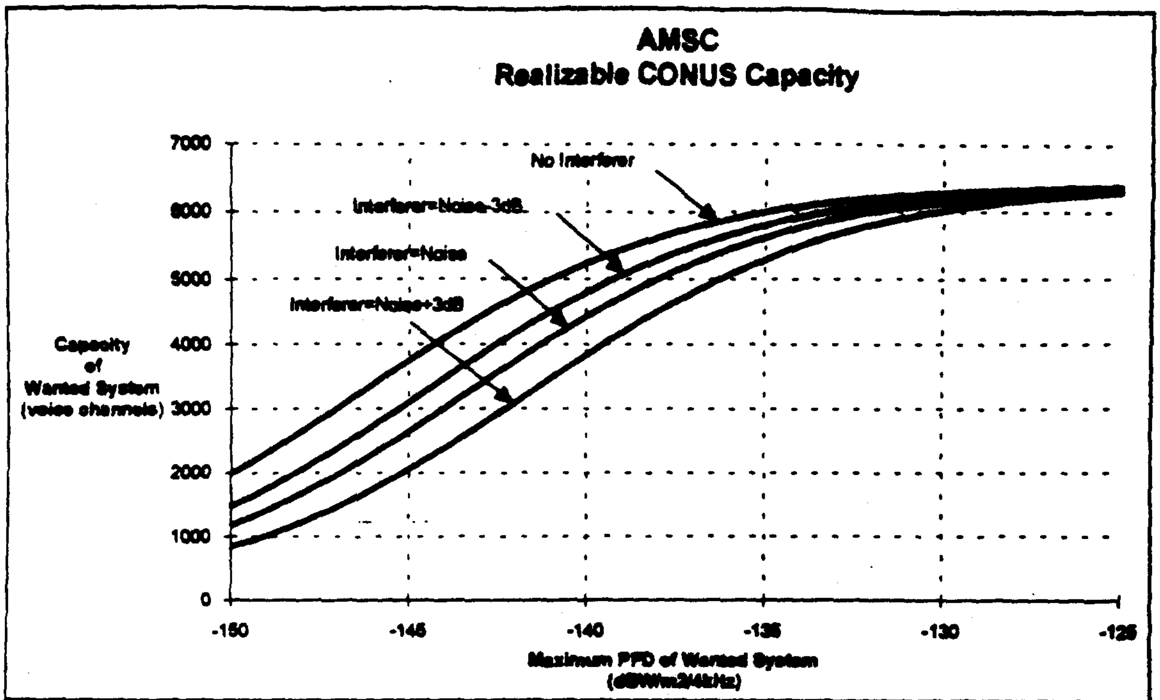

Figure 1 (Downlink, 16.5 MHz)

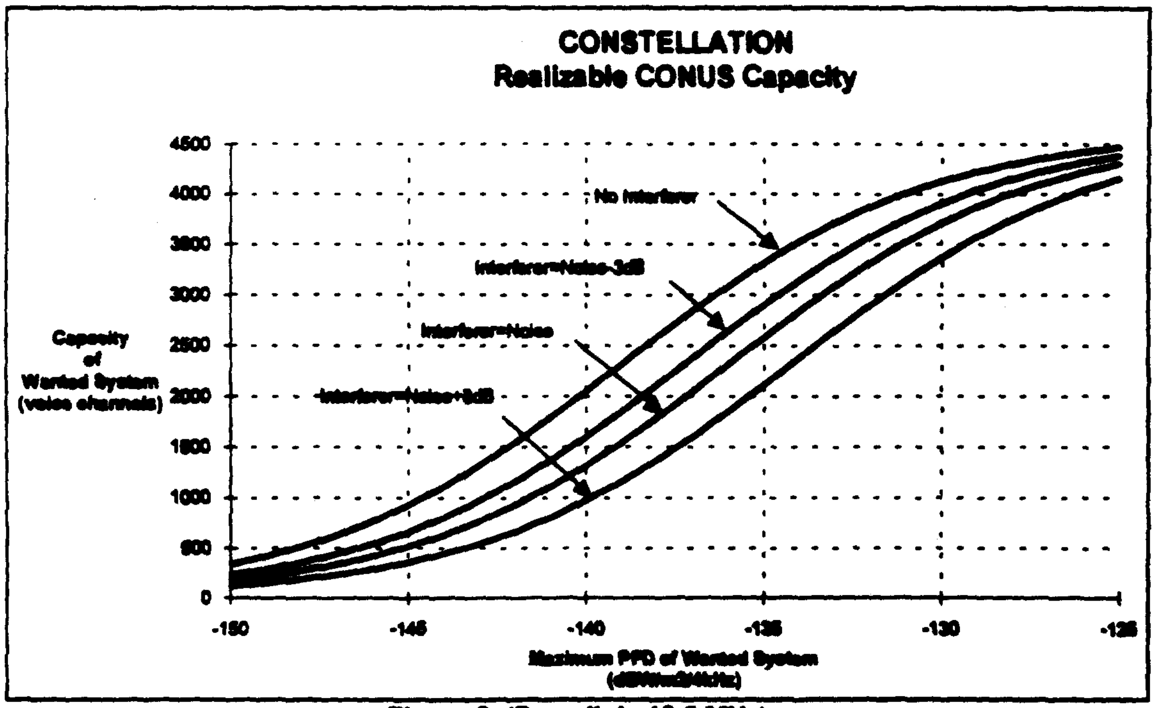

Figure 2 (Downlink, 16.5 MHz)

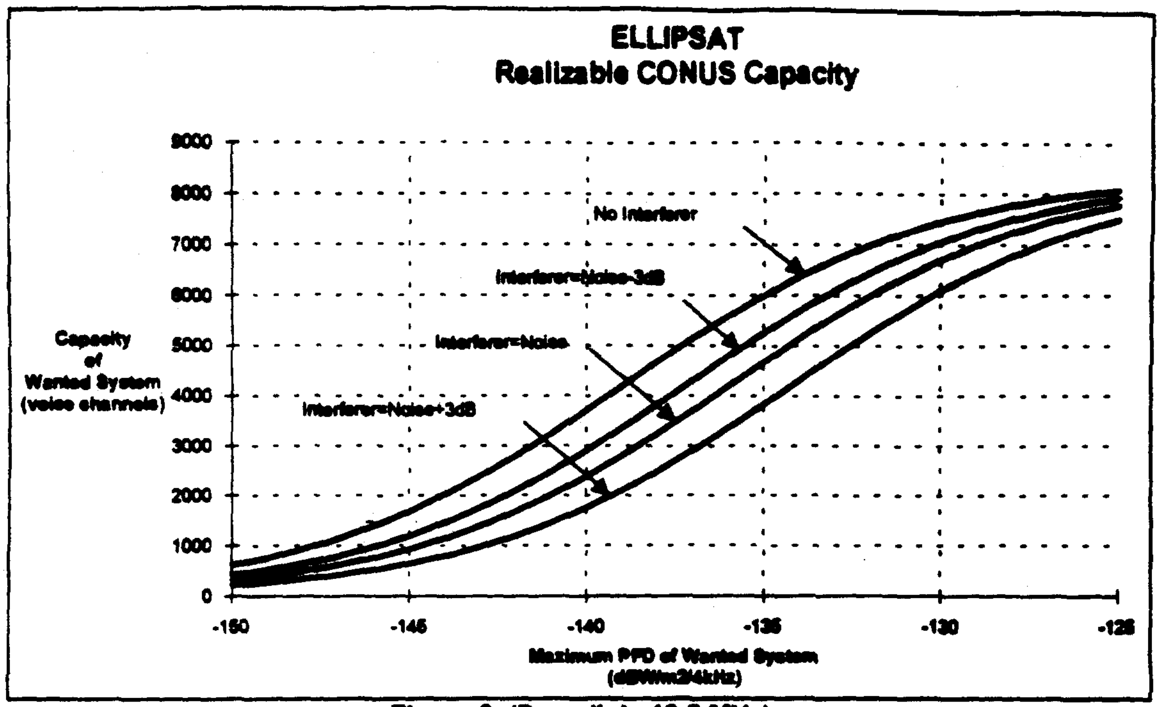

Figure 3 (Downlink, 16.5 MHz)

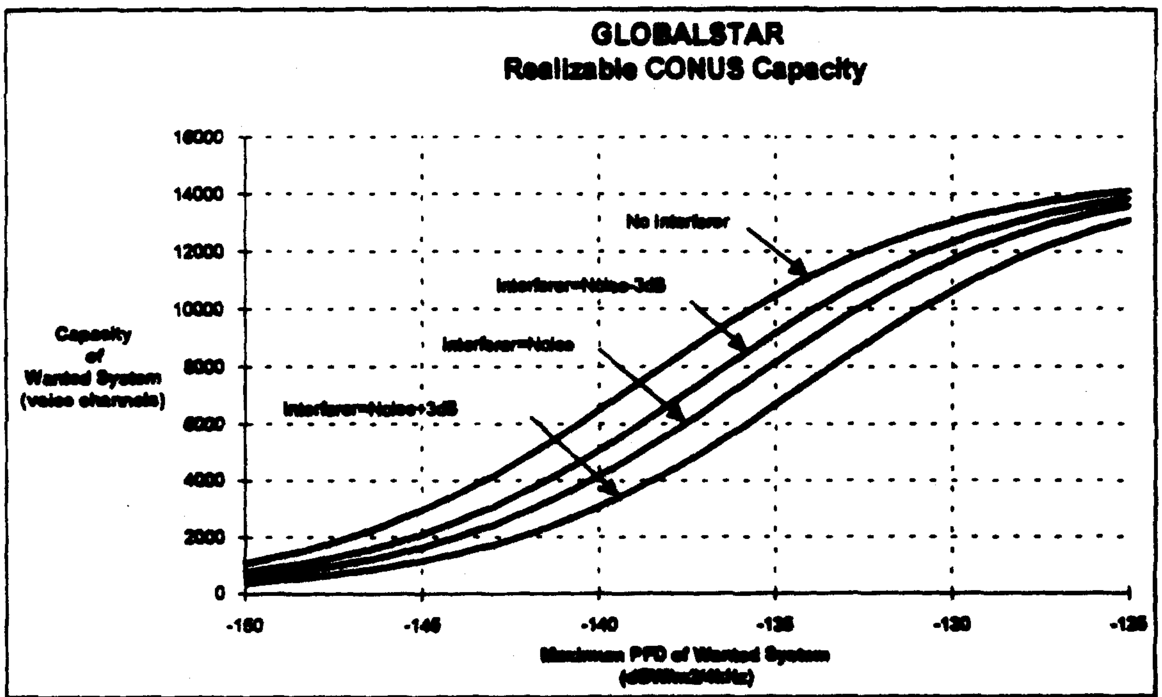

Figure 4 (Downlink, 16.5 MHz)

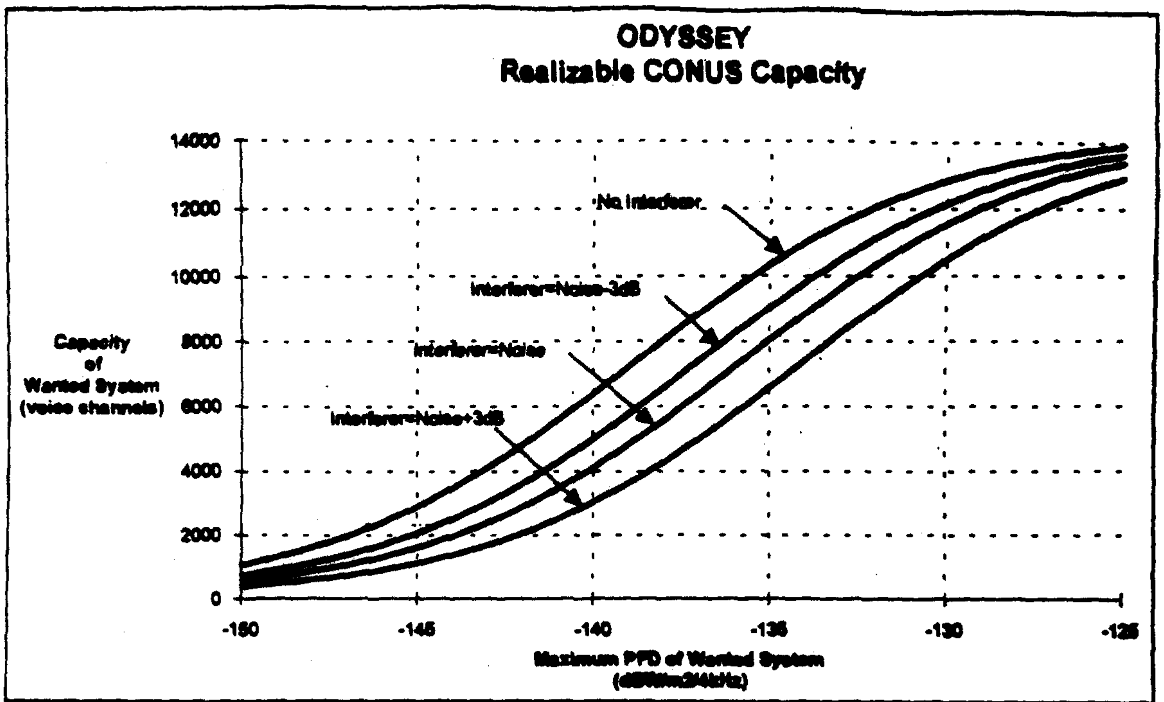

Figure 5 (Downlink, 16.5 MHz)

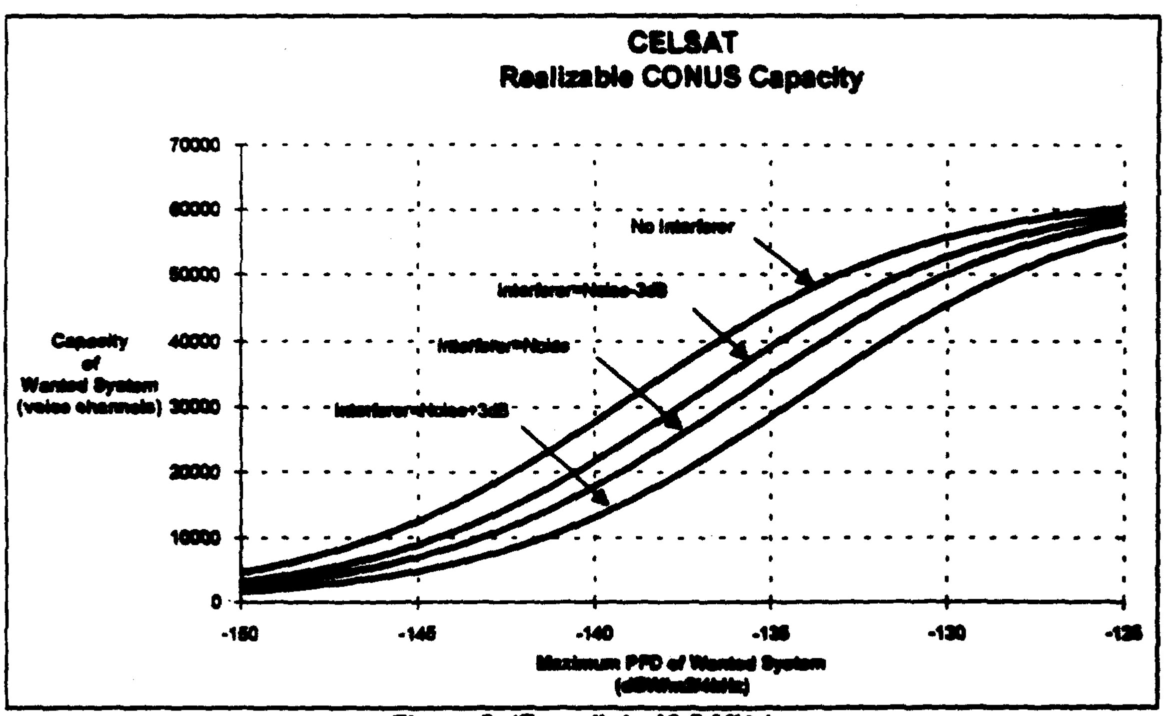

Figure 6 (Downlink, 16.5 MHz)

5.1.3.2 Collective Combined System Capacities (16.5 MHz Bandwidth)

This section addresses the collective CONUS downlink capacity achievable when the MSS systems analysed in section 5.1.3.1 are assumed to be operating simultaneously, co-frequency and co-coverage. In this section the full 16.5 MHz bandwidth is assumed to be available. All systems are assumed to be operating using orthogonal CDMA in the downlink. Constellation, Ellipsat, Globalstar and Odyssey are assumed to use dual satellite diversity. This is taken into account by modifying equation (5) in section 5.1.2.2 above, as follows:

$$C_{RD} = (C_{MRD} \cdot \rho_{sd}) / (\alpha\rho_{sd} + \rho_{nd} + \rho_{id}) \quad (6)$$

where α = 0 with no satellite diversity
= 0.5 with dual satellite diversity

The achievable individual and collective downlink capacities when multiple CDMA systems are in operation will depend on the amount of PFD used by each system. There are therefore numerous permutations of varying amounts of this resource to each system that can be analysed.

Table 2 gives eleven example scenarios (described below) when all systems are assumed to be operating co-polar, showing the maximum PFD in use by each system, the corresponding realizable capacity of that system, and the aggregate CONUS capacity (the sum of all the systems).

Scenario - Downlink	AMSC	Constell'n	Ellipsat	Globalstar	Odyssey	Celsat	Total
Case 1: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-142.0	-142.0	-142.0	
Resulting Capacity (# ccts)	1198	619	1119	1966	1927	8957	15776
Case 2: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0	-139.0	-139.0	
Resulting Capacity (# ccts)	1239	714	1291	2256	2223	10448	18174
Case 3: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-142.0	-142.0		
Resulting Capacity (# ccts)	1473	714	1291	2256	2223	0	7958
Case 4: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0	-139.0		
Resulting Capacity (# ccts)	1536	844	1525	2886	2827	0	9190
Case 5: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0			
Resulting Capacity (# ccts)	2019	1032	1864	3258	0	0	8173
Case 6: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0		-139.0		
Resulting Capacity (# ccts)	2019	1032	1864	0	3210	0	8125
Case 7: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-139.0	-139.0		
Resulting Capacity (# ccts)	1011	547	968	3861	3806	0	9916
Case 8: Max. PFD (dBW/m2/4kHz)		-142.0	-142.0	-139.0	-139.0		
Resulting Capacity (# ccts)	0	620	1120	4184	4123	0	10046
Case 9: Max. PFD (dBW/m2/4kHz)			-142.0	-139.0	-139.0		
Resulting Capacity (# ccts)	0	0	1293	4882	4811	0	10986
Case 10: Max. PFD (dBW/m2/4kHz)				-139.0	-139.0		
Resulting Capacity (# ccts)	0	0	0	5858	5773	0	11631
Case 11: Max. PFD (dBW/m2/4kHz)				-139.0	-139.0	-142.0	
Resulting Capacity (# ccts)	0	0	0	4882	4811	10464	20157

<u>Table 2 (co-polar: available bandwidth = 16.5 MHz)</u>

The use of orthogonal polarization transmissions to increase isolation between potentially interfering MSS systems has been studied. The achievable isolation is very dependent on the propagation path, and the minimum isolation values have not been sufficient to permit this technique to be used to allow frequency re-use in co-coverage, co-frequency FDMA MSS systems. However, in a CDMA system any achievable isolation can be used to increase total spectrum capacity. The relevant isolation is the average achievable, and not the worst case. The following two tables demonstrate the impact on CDMA system capacity of using orthogonal polarization, using two representative values of achievable polarization isolation: 3 dB and 6 dB.

Table 3 gives the same eleven example scenarios but with the use of orthogonal polarizations between some of the systems (Right Hand Circular (RHC) and Left Hand Circular (LHC)). AMSC, Ellipsat and Globalstar are assumed to use RHC polarization and Constellation, Odyssey and Celsat are assumed to use LHC polarization. An average polarization isolation of 6 dB between RHC and LHC is assumed in these results.

Scenario - Downlink	AMSC (RHC)	Constell'n (LHC)	Ellipsat (RHC)	Globalstar (RHC)	Odyssey (LHC)	Celsat (LHC)	Total
Case 1: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-142.0	-142.0	-142.0	
Resulting Capacity (# ccts)	2064	884	1597	2791	2750	13184	23269
Case 2: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0	-139.0	-139.0	
Resulting Capacity (# ccts)	2189	1091	1972	3446	3396	16884	28788
Case 3: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-142.0	-142.0		
Resulting Capacity (# ccts)	2245	928	1677	2931	2888	0	10668
Case 4: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0	-139.0		
Resulting Capacity (# ccts)	2394	1160	2096	3662	3609	0	12821
Case 5: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0	-139.0			
Resulting Capacity (# ccts)	2642	1237	2236	3907	0	0	10022
Case 6: Max. PFD (dBW/m2/4kHz)	-139.0	-139.0	-139.0		-139.0		
Resulting Capacity (# ccts)	3818	1545	2792	0	4809	0	12966
Case 7: Max. PFD (dBW/m2/4kHz)	-142.0	-142.0	-142.0	-139.0	-139.0		
Resulting Capacity (# ccts)	1564	743	1343	5088	5014	0	13752
Case 8: Max. PFD (dBW/m2/4kHz)		-142.0	-142.0	-139.0	-139.0		
Resulting Capacity (# ccts)	0	886	1596	6157	6068	0	14708
Case 9: Max. PFD (dBW/m2/4kHz)			-142.0	-139.0	-139.0		
Resulting Capacity (# ccts)	0	0	1679	6501	6406	0	14586
Case 10: Max. PFD (dBW/m2/4kHz)				-139.0	-139.0		
Resulting Capacity (# ccts)	0	0	0	8356	8234	0	16590
Case 11: Max. PFD (dBW/m2/4kHz)				-139.0	-139.0	-142.0	
Resulting Capacity (# ccts)	0	0	0	7797	7683	16716	32196

Table 3 (cross-polar isolation = 6 dB; available bandwidth = 16.5 MHz)